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EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF FINE AGGREGATE WITH SCRAP TYRE RUBBER IN FOAMED CONCRETE

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Abstract:

In recent decades, the worldwide growth of the automobile industry and the increasing use of cars as the main means of transport have tremendously boosted tyre production. This has generated massive stockpiles of used tyres. Extensive research projects were carried out on how to use used tyres in different applications. In order to properly dispose these millions of tyres, the use of innovative techniques to recycle them is important. The use of scrap tyres including tyre chips or tyre shreds comprised of pieces of scrap tyres, tyre chips/soil mixtures, tyre sidewalls, and whole scrap tyres in civil engineering applications is the objective.

1. Introduction:

The scarcity and availability at reasonable rates of sand are now giving anxiety to the construction industry. Over years deforestation and extraction of natural aggregates from river beds, lakes and other water bodies have resulted in huge environmental problems. Erosion of the existing topography usually results in flooding and landslides. The best way to overcome this problem is to find alternate aggregates for construction in place of conventional natural aggregate. Rubber aggregates from discarded tyre rubber in sizes 20-10 mm, 10-4.75 mm and 4.75 mm down can be partially replaced natural aggregates in concrete. In this project work we have done research on partial replacement of sand with scrap tyre rubber in light weight foam concrete by introducing rubber phases among the traditional components (cement, water, and aggregates). Different proportions of scrap tyre rubbers have been employed as partial substitute of natural sand with some percentage of chemical admixtures like silica fume and fly ash to enhance the strength of the concrete. During the last years, several researches have been studying the final disposal of elastomeric wastes, due to the great volume generated worldwide, as well as the difficulty for establishing disposal sites which become a serious environmental problem. In spite of this, recycling appears as the best solution for disposing elastomeric residues, due to its economical and ecological advantages. On the other hand, the conception of products for concrete is also increasing, due to the high growth of construction in the past years. Even though concrete based on Portland cement is one of the most extraordinary and versatile elements in construction, there is a need modifying its properties, such as tensile, hardness, ductility and recycling rubber simultaneously is to combine both materials. Hence the main objective of this paper is to bring awareness about foamed concrete which shows advantage against reduced dead load in addition of scrap rubber as reusable material.

2. Experimental Design:

Over View: The main aim of this research is to utilise the waste rubber tyres in lightweight concrete as fine aggregate and to identify the properties of the mixture and its fresh and hardened concrete properties. The concrete mixing was performed in Material Testing Laboratory at Ranganathan Engineering College, Coimbatore. Before mixing commenced the gradation of scrap rubber samples was determined and compared with the natural aggregates.

Physical Properties of Cement: Physical properties of the ordinary Portland cement (53 grade) such as specific gravity, fineness, normal consistency, initial and final setting time and mechanical property ie, compressive strength are determined as per the procedure given below.

Specific Gravity: Specific gravity of the cement can be determined as the following procedure. Weigh a clean and dry Le Chatelier Flask or Specific gravity bottle with its stopper (W_1). Place a sample of sample of cement up to half of the flask (about 50 gm) and weigh with its stopper (W_2). Add kerosene (polar liquid) to cement in flask till it is about half full. Mix thoroughly with glass rod to remove entrapped air. Continue stirring and add more kerosene till it is flush with the graduated mark. Dry the outside and weigh (W_3). Entrapped air may be removed by vacuum pump, if available. Empty the flask, clean it refills with clean kerosene flush with the graduated mark, wipe dry the outside and weigh (W_4).

$$\text{Specific Gravity} = \frac{(w2-w1)}{(w2-w1) - (w3-w4) \times 0.79}$$

The value of specific gravity is shown in Table 4.2.4.2

Fineness: In order to determine the fineness of the cement, Weigh accurately 100gm of cement and place it on a standard IS sieve 90 microns. Break down any air set limps in the sample with fingers, but do not rub on the sieve. Continuously sieve the sample by holding the sieve in both the hands and giving a gentle wrist motion or mechanical sieve shaker may be used for this purpose. The sieving should be continuous for 15 minutes. Weigh the residue left after 15 minutes sieving. This residue shall not exceed the specified limits.

Normal Consistency: To find normal consistency, Weigh about 400 gm of cement accurately and place it in the enamel trough. To start with, add about 25% of clean water and mix it thoroughly with cement. Care should be taken that the time of gauging is not less than 3 minutes and not more than 5 minutes. The gauging time shall be counted from the time of adding water to dry cement until commencing to fill the mould. Fill the vacant mould with this paste, Make the surface of the cement paste in level with the top of the mould with a trowel. The mould should be slightly shaken to expel the air. Place this mould under the rod bearing the plunger. Adjust the indicator to show 0-0 reading when it touches the surface of the block. Release the plunger quickly, allowing it to sink into the paste. Prepare trial pastes with varying percentage of water and the test is repeated as described above until the needle penetrates 5 mm to 7 mm above the bottom of the mould. Express this amount of water as a percentage by weight of the dry cement. The value obtained is shown in Table.

Initial and Final Setting Time:

Initial Setting Time: Weigh about 400gm of neat cement. Prepare a neat cement paste by adding 0.85 times the percentage of water required for standard consistency. Start the stop watch at the instant when the water is added to the cement. Fill the vacant mould with the cement paste prepared. Gauging time should not be less than 3 minutes and more than 5 minutes. Fill the mould completely and smooth of the surface of the paste, making it level with the top of the mould to give a test block. Place the test block confined in the mould under the rod bearing the needle. Lower the needle gently till it comes with the surface of the test block and quickly release, allowing it to penetrate the test block and note the penetration after every 2 minutes. Repeat this procedure until the needle fails to pierce the block for about 5 mm, measured from the bottom of the mould. Stop the stop watch and note the time, which is the initial setting time.

Final Setting Time:

- ✓ Replace the needle with an angular attachment.
- ✓ Go on releasing the needle as described earlier till the needle makes an impression there on, while the attachment
- ✓ Time that elapsed between the moments when water is added to the cement and the needle makes only an impression is considered as final setting time.

The initial and final setting time of the cement is shown in the table. Test results of physical properties of cement.

Properties	IS Code	Values Obtained	Standard value
Specific gravity	IS 4031 (Part 1) - 1988	3.15	-
Fineness	IS 4031 (Part 1) -1988	5%	<10
Normal Consistency	IS 4031 (Part 4) - 1988	30%	-
Initial Setting time	IS 4031 (Part 5) - 1988	65 minutes	>30
Final Setting time	IS 4031 (Part 5) – 1988	195 minutes	<600

Physical Properties of Fine Aggregate: The aggregate fraction ranging from 4.75 mm to 150 micron are termed as fine aggregate. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. Physical properties of fine aggregate such as specific gravity, maximum % bulking, fineness modulus, zone determination etc are done as per the procedure given below.

Specific Gravity: Clean and dry Pycnometer or specific gravity bottle with its stopper is weighed (M1). A sample of wet sand, about 200 to 400 gm, is taken in the pycnometer and weighed (M2). Water is then added to the sand in the pycnometer to make it about half full. The contents are thoroughly mixed using a glass rod to remove the entrapped air. More and more water is added and stirring process continued till the pycnometer is filled flush with the hole in the conical cap. The pycnometer is wiped dry and weighed (M3). The pycnometer is then completely emptied. It is washed thoroughly and filled with water, flush with the top whole. The pycnometer is wiped dry and weighed (M4).

$$\text{Specific gravity} = (M2 - M1) / ((M2 - M1) - (M3 - M4))$$

Specific gravity of the fine aggregate is shown in table

Bulking of Sand:

- ✓ Take about 200 gm of the sand from the sample and find its weight.
- ✓ Add water at 2% by weight of dry sand and mix it thoroughly in the tray by hand.
- ✓ Pour the damp sand in the measuring cylinder (consolidated by shaking) and note its volume (V).
- ✓ Repeat the test with different percentage of water(at 2% increment)
- ✓ Finally pour water into the measuring cylinder containing the moist sand sufficient to submerge the sand completely. Stir the sand well.
- ✓ Allow the sand to settle and it will be seen that the sand surface is now below its original level. Note down the volume (V_0).
- ✓ Calculate the percentage bulking for each percentage of water added by using the equation

$$\% \text{ bulking} = (V - V_0) \times 100 / V_0$$

The value of maximum % bulking obtained is shown in table 2.3.4

Sieve Analysis: Sieve analysis is the operation of dividing a sample of aggregate into various fractions each consisting of particles of same size. Sieve analysis is conducted to find the gradation. We conducted this test for fine aggregate. The sieves used for analysing fine aggregate are 4.75 mm, 2.36 mm, 600µ, 300µ and 150µ. The zone of fine aggregate is represented in table V

Fineness Modulus: Fineness modulus is a term indicating coarseness or fineness of the material. It is obtained by adding the cumulative percentage of aggregate retained on each of the sieve and dividing them by 100.

$$\text{Fineness modulus} = \Sigma \text{ cumulative percentage retained} / 100$$

The results of physical properties of the fine Aggregate are shown in table. Tests on Fine Aggregate

Properties	IS Code	Values Obtained
Specific gravity	IS 2386(Part 3)-1963	2.47

Maximum % bulking	IS 2386(Part 3)-1963	40
Fineness Modulus	IS 2386(Part 1)-1963	3.08
Zone	IS 2386(Part 1)-1963	2

3. Materials:

Scrap Tyre Rubber: Scrap tire rubber powder can be obtained from tires through two principal processes:

- ✓ ambient, which is a method in which scrap tire rubber is ground or processed at or above ordinary room temperature and
- ✓ cryogenic, a process that uses liquid nitrogen to freeze the scrap tire rubber until it becomes brittle and then uses a hammer mill to shatter the frozen rubber into smooth particles

For this study, the rubber powder was collected from the used automobile tires by mechanical shredding at ambient temperature. Steel was removed by magnetic separation and one part of textile fibre was removed by density.

Scrap Rubber

Characteristics of the Scrap Tyre Rubber:

Physical Characteristics:

Properties	Rubber powder
Density	0.83
Size	80 µm – 1.6 mm
Elongation (%)	420
Rate of steel fibre	0%

The used specimens don't contain steel but contain less than 2% of textile fibre. Since it was not possible to determine the gradation curve of the rubber powder as for normal aggregates, a microscope examination was done. Dimensions of rubber powder vary from 1.6 mm to 0.8 mm with an average particle size of 1 mm. The density of the rubber powder is determined using helium pycnometer and it's about 0.83. Rubber powder is also characterized by insignificant water absorption less than 3%.

Rubber Powder Characteristic:

Material/Element	Mass Percentage
Rubber	54%
Carbon black	29%
Textile	2%
Oxidize zinc	1%
Sulphur	1%.
Additives	13%

Foaming Agent: Foaming agents is also defined as air entraining agent. Air entraining agents are organic materials. When foaming agents added into the mix water it will produce discrete bubbles cavities which become incorporated in the cement paste. The properties of foamed concrete are critically dependent upon the quality of the foam. .

Foam Generator: There are three main parameters to control the foam generator:

- ✓ Water flow
- ✓ Water to concentrate ratio
- ✓ Air pressure

Water Flow: The water flow is difficult to influence, hence provide valve between the water tube and the foam generator. From this work the average water flow inside of the HIF water supply system is known with an average flow.

Water to Concentrate Ratio: The amount of concentrate, which goes into the generator by means of a special pump, can be continuously adjusted by a controller. One test series regarding this parameter, taken care of the range which is given by the producer, therefore new tests have been done to get the information about the water to concentrate ratio out with the recommended range.

Air Pressure: A manometer controls the air pressure at the generator. According to Herbst, the air pressure is the best way to control density of the foam. It is relatively easy to vary the air pressure. To produce foams with different water to concentrate ratio and equal air pressure the manometer had to be readjusted

Generating Foam

Super Plasticizer:

A chemical admixture is any chemical additive to the concrete mixture that enhances the properties of concrete in the fresh or hardened state. A number of types of chemical admixtures are used for concrete. The general purpose chemicals include those that reduce the water demand for a given workability. Super plasticizers also known as high range water reducers are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation and to improve the flow characteristics of suspensions. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture and enables the production of self-consolidating concrete and high performance concrete. The new generation of this kind of admixtures is represented by polycarboxylate ether based super plasticizers (PCEs). With a relatively low dosage (0.15-0.3% by cement weight) they allow a water reduction up to 40% due to their chemical structure which enables good particle dispersion.

Superplasticizer

Test on Rubber:

The rubber aggregates used in the present investigation were made by mechanically cutting the tire in to the required sizes. It was very laborious, time consuming and was not easy to handle at the initial stages. However, all this complications can be easily sorted out if a large scale production is devised and proper cutting tools and machineries are made for this particular usage. Source of rubber aggregates is the discarded tyre that is, trucks tyre which is collected from the local market and rubber tyre fine aggregates are prepared from tyre remoulding shop in ukkadam as shown in Figure I. The rubber aggregates used in present study are prepared mechanically by cutting the tyres to maximum nominal size equal to 4.75 mm as shown in Figure and kept for air drying after cleaning with potable water. The specific gravity is obtained from test equal to 1.10.

4. Results and Discussion:

Over View: The chapter discuss the results obtained from various tests. The results presented in this chapter are the average results obtained during experiment.

Gradations: The sieve analysis of the scrap tyre rubber samples revealed that the material was a combination of both fine and coarse sized. The figure shows the results of sieve analysis. The scrap tyre rubber of size less than 2.36 mm is chosen as fine aggregate replacement. Recommended natural sand gradation and the results of sieve analysis of sand are shown in table 6.2. Gradations

Sieve Size	Recommended Sand Gradation %Passing	Sand Used % Passing
4.75 mm	100	100
2.36 mm	95 to 100	97.1
1.18 mm	70 to 100	84.3
600 micron	40 to 75	62
300 micron	10 to 35	29
150 micron	2 to 15	11.5

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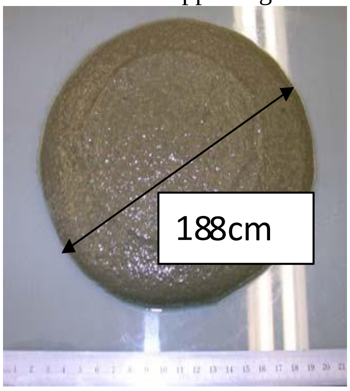
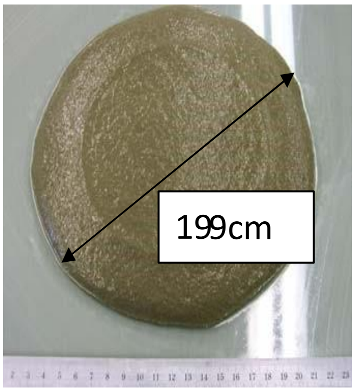
Replacement of Fine Aggregate in Concrete: The experimental program was designed to study the mechanical properties of concrete with partial replacement of fine aggregate by scrap rubber. The compressive ,tensile and flexural strength of the specimens after replacing the fine aggregate by 20% and 30% with scrap rubber is studied after 7,21 and 28 days of curing.

Fresh Concrete Properties: Fresh concrete properties such as slump test were conducted as per Indian Standards. The vertical settlement is known as slump. In the slump test fresh concrete is filled in a mould of specified shape and dimension and settlement or slump is measured when the supporting mould is removed.





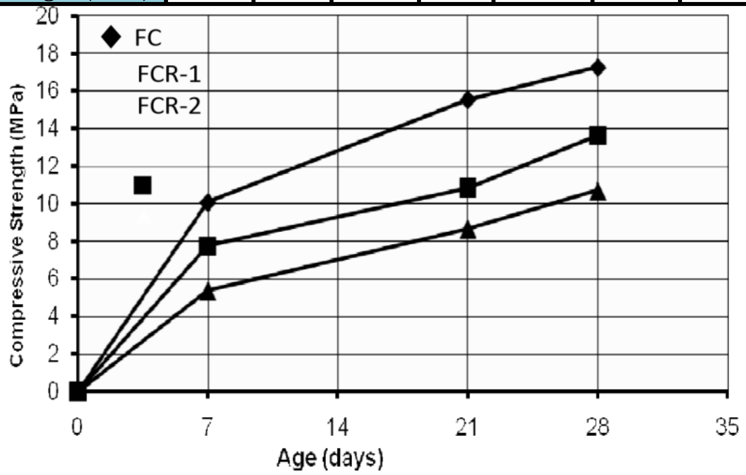
Fresh Concrete Properties

Mainly the aspect of W/C ratio and the foam volume influenced the spread of the large slump tests. An increase in the spread could be seen with a higher W/C ratio and higher foam volume. The spreads with the mixtures with fibres are hard to compare with the other spread tests.

Compressive Strength: The compressive strength was determined by dividing the ultimate applied load by the cross sectional area of the concrete. The values obtained for the compressive strength for concrete specimens are given below

Compressive Strength

Mix	FC			FCR1			FCR2		
	0%			10%			20%		
Age (days)	7	21	28	7	21	28	7	21	28
Average Density(Kg/m^3)	1702	1710	1715	1585	1595	1605	1515	1524	1529
Compressive Strength (MPa)	10.08	15.56	17.21	7.75	10.83	13.62	5.38	8.67	10.71

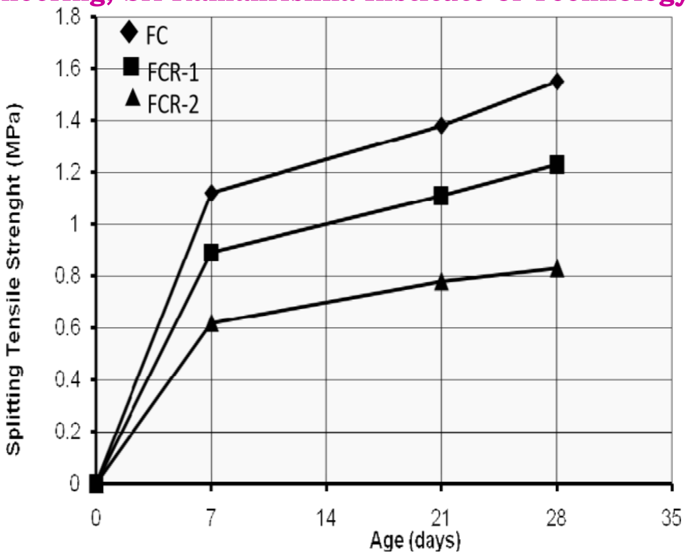


The relationships between the compressive strength and age

Spiting Tensile Strength: The Spiting tensile strength of concrete specimen tested. The specimen was tested on split tension machine.

Results of Spiting tensile strength test for the selected mixes

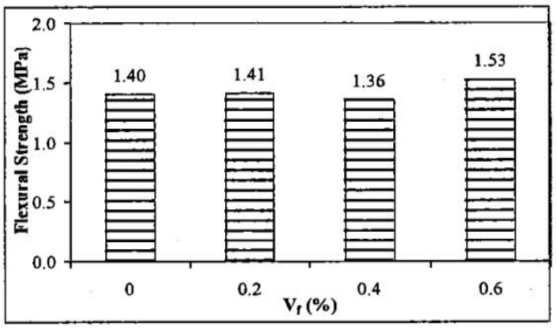
Mix	FC			FCR1			FCR2		
	0%			10%			20%		
Age (days)	7	21	28	7	21	28	7	21	28
Average Density(Kg/m^3)	1705	1715	1727	1578	1588	1591	1512	1519	1526
Spiting Tensile Strength (MPa)	1.12	1.38	1.55	0.89	1.11	1.21	0.62	0.78	0.83



The relationships between Fsp and age of the test for all selected mixes

Flexural Strength of Concrete: The presence of polyolefm fibres appears to increase marginally the flexural strength from 1.40 MPa to 1.53 MPa for 0.6 % fibre volume fraction as shown in Figure 4. These values represent a percentage of 0.7 %, -2.9 % and 9.3 % for PFC 0.2, PFC 0.4 and PFC 0.6 mixes. Its also founded that increasing about 20 % in flexural strength for polypropylene fibre reinforced light weight aggregate concrete at 0.56 % by volume fraction. The reason for the increase of flexural strength is the fracture process of polyolefin fibre reinforced foamed concrete consists of progressive debonding of fibre have slowed down the crack propagation.

Flextural Strength Testing



Flexural strength test results of concrete at different volume fractions.

The typical flexural load-deflection curves of polyolefin fibre reinforced foamed concrete with fibre volume fractions of 0.2 %, 0.4 % and 0.6 % are shown in Figure 5.2. The test results show that the load-deflections curve for polyolefm fibre reinforced foamed concrete are similar to the curves for polyolefm fiber reinforced concrete described by 3M Corp [8]. It observed that the linear elastic part of the curves appear before the ultimate load

5. Conclusion:

According to the experimental work and from the analysis of results obtained, the following conclusions can be drawn: A partial sand Replacement in foamed concrete by crumb tyres rubber leads to reduce the density of the final product, because of the specific gravity of rubber used was less than it of sand. Water absorption (%) increases with increasing of crumb rubber of tyres content. Decreasing in rubberized foamed concrete strength (compressive, tensile, flexural, and impact) with the increasing of crumb rubber of tyres content in the mixture was always detected. Rubberized foamed concrete (FCR-1 and FCR-2) show a cohesive behaviour at failure than foamed concrete (FC), and this is obviously appear in Spiting tensile test. Addition of rubber cause deceasing in foamed concrete strength, in spite of this, in many applications high strength concrete is not essential; therefore, recycling the waste of tyres rubber by using it in foamed concrete that used for non-structural purposes will achieve economical and ecological advantages.

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